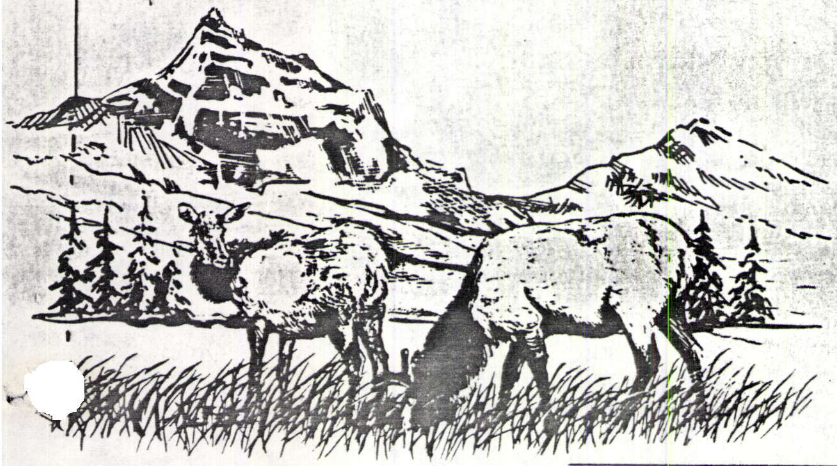
METHODOLOGY for

RECLAMATION / REVEGETATION of URANIUM MINED LANDS in UTAH and COLORADO

Prepared for
ATLAS MINERALS

SEPTEMBER, 1982



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METHODOLOGY FOR RECLAMATION/REVEGETATION OF URANIUM MINED LANDS

Prepared For

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1.0 INTRODUCTION

This report has been prepared to assist Atlas Minerals in complying with regulatory requirements of the Utah Division of Oil, Gas and Mining, and the Colorado Mined Land Reclamation Division of the Department of Natural Resources. Atlas has 21 permitted uranium mine operations in Utah and 20 in Colorado. Currently, only two operations are being actively mined by Atlas Minerals, both in Utah. The Utah and Colorado reclamation and revegetation requirements stem from State mined land reclamation acts which became effective in Utah on July 1, 1977, and in Colorado on July 1, 1976. Mining operations which were active after passage of the State acts must comply with the requirements of the acts. Operations which were inactive prior to passage of the acts, and which have remained inactive, need not comply with requirements of these acts.

2.0 LITERATURE REVIEW AND ANALYSIS

2.1 GENERAL

The major issue in planning reclamation strategy is to restore and reestablish a functioning stable ecosystem on mined land, minimize formation of environmental pollutants and contamination of adjacent undisturbed areas. Reclamation must take a broad approach which encompasses numerous disciplines. Revegetation is overall one of the most important aspects of reclamation since establishment of a continuous vegetation cover has several prerequisites: suitably contoured and regraded slopes, sufficient depth of moderately fertile and non-toxic soil, control of surface water flow to minimize erosion and gullying, and selection of suitably adapted plant species which can maintain themselves under these conditions. Vegetation itself is a principal agent in reducing erosion hazards by decreasing runoff and increasing infiltration. It stabilizes the soil surface, reduces blowing dust, and with time, improves soil properties while deep-penetrating roots physically stabilize the surficial mass.

The approach and design of revegetation procedures are directed by certain site-specific constraints and by general objectives for reclamation. In the mining industry, economics dictate utilization of procedures which promise good likelihood of success at a reasonable cost. These procedures ultimately must restore the mining site to a productive use similar to pre-mining land uses or suitable alternative uses. These may include agriculture, forestry, industry, housing, recreation, watershed, or fish and wildlife habitat. Reclaimed land may be as productive as the pre-mining state, though the new land use may be different.

Numerous authorities stress the importance of comprehensive mine planning with reclamation as an integral part of the entire process (Cook; 1976; Bradley, 1977; Kesten, 1977). They consider mining a short-term use of the land with efforts directed towards planning a long-term post-mining land use emphasizing ecological stability. Aesthetic considerations and the final appearance of reclaimed areas can frequently be incorporated into reclamation activities at little additional cost, so that final configurations are not only ecologically stable but pleasing to the eye.

Important general constraints which guide reclamation planning (O'Neill, 1977) have been incorporated into the Atlas Minerals' plans and consider: 1) the post-mining topography, intended land use and degree of land disturbance, 2) chemical properties of the mining wastes, 3) physical properties of the wastes, 4) economics of the mining and reclamation plan, and 5) climatic factors.

2.2 GENERAL PRINCIPLES OF REVEGETATION

The key to successful revegetation is in establishing soil, nutrient and moisture conditions in which plants can successfully grow. The wide variety of reclamation techniques and procedures generally have the objective of improving conditions in the plant growth environment so that plants will successfully germinate, establish, grow and reproduce. Favorable conditions are required in all four of these life cycle phases for the vegetation community to be self sustaining. If conditions are unfavorable in one of these phases, eventually the vegetation community will deteriorate.

Numerous range scientists and revegetation workers have described some of the basic principles also of successful revegetation. Plummer, Christensen and Monsen (1968) emphasize restoration of big-game range in Utah, but their principles apply to mined-land revegetation. In all plantings, they emphasize the need for adherence to the following principles:

- Terrain and soil type must be suitable to the type of revegetation proposed
- Precipitation must be adequate to assure establishment and survival of planted species

- Competition must be low enough to assure that the desired species can become firmly established
- Only species and strains of plants adapted to the area should be planted
- Mixtures of plant types rather than single species should be planted
- Sufficient seed of acceptable purity and viability should be planted to insure getting a stand
- Seed must be covered sufficiently
- Planting should be done in a season that gives promise of optimum conditions for establishment
- The planted areas must not be overgrazed

McKell, et. al. (1979) emphasize selection, propagation and field establishment of native species as important factors in revegetation programs. Appropriately adapted ecotypes of plant species must be chosen for each arid site, and as the harshness of the site increases, fewer species are capable of surviving and reproducing. Thus the importance of using the appropriate species and suitable propagation techniques (seeding, transplanting, stem cuttings, vegetative reproduction, etc) increases on more arid sites. Easily propagated species should be favored. Soil properties directly affect revegetation success, and basic agronomic properties should always be analyzed to determine if amendments are needed to enhance revegetation. Field conditions which might prevent or inhibit seed or plant establishment should be evaluated prior to planting to minimize chances of revegetation failures.

Hodder (undated manuscript) succinctly describes two general approaches to arid land revegetation: 1) put the plant roots down below the dry upper soil layer to zones where soil is moist or; 2) bring the soil moisture up to the level of the plant root system. He worked with small-diameter, long (2½" x 24") shrub tubelings, to get the roots to the level of soil moisture. Alternatively, shrub-planting basins covered with a plastic sheet caused condensation of soil moisture on the underside of the plastic, with the moisture able to sustain the shrub. These techniques were successful on dryland highway roadside shrub plantings on the arid plains of eastern Montana.

The above brief descriptions of revegetation principles and techniques provide an overview of major types of considerations in revegetation plantings. The following sections will give more specific examples of other techniques and practices currently in use.

2.3 SOIL AND MOISTURE CONSERVATION TECHNIQUES

Because all of Atlas' mine sites have limited annual precipitation (approximately 6 to 18 inches annually), moisture conservation techniques will be important in reestablishing plants on barren waste rock spoils. The prerequisites of plant nutrients, water, and adapted plant species must be placed together with a coordinated timing that allows sustained growth. The following techniques describe how this can be done to help improve the potential for successful revegetation in semi-arid environments.

Water availability for vegetation growth can be increased by impeding runoff, increasing infiltration and reducing evaporation. Suitable techniques include gradient reduction, cultivation, mulching, topsoiling, buffering, surface soil manipulations, compaction relief and special seeding techniques (Hodder, 1977). By reducing the slope gradient, runoff is diminished, infiltration increased and opportunities for seed-bed preparation are improved by allowing use of machinery. Cultivating the surface increases infiltration, reduces upward movement of capillary water, and reduces evaporation so more moisture is available for plant roots. Various types of surface mulches increase water infiltration, diminish evaporation, and ameliorate temperature extremes at the soil surface. Effective mulches include straw from various crops or volunteer weeds, (Day, et. al., 1979), jute netting, sewage sludge, wood chips and sawdust, and other organic, high bulk substances. These additives enhance seedling establishment (Hodder, 1977).

The effectiveness of mulches varies with the particular site being seeded and plant species in use. In semi-arid southwestern Wyoming, research was conducted on spoil banks using jute netting, jute and barley straw mulch, and light wire net and barley straw mulch. The barley straw was spread evenly after broadcasting a mix of grass seed. Wire and jute nets were then placed to secure the straw. On spoil banks of three different ages (3, 9, 15 years), average seedling numbers per square foot were:

jute netting only	109
jute and mulch	137
wire and mulch	115
control (bare spoil)	17

All three treatments gave substantially higher seedling numbers than the control; among the mulched treatments, jute and mulch gave best grass seedling establishment (May, et. al., 1971).

On coal mine spoils in western North Dakota, a straw mulch reduced soil loss about 66 percent over comparable bare surfaces. Mulch quantities were applied to achieve soil surface coverage comparable to adjacent, undisturbed rangeland vegetation (Gilley, 1980).

Soil surface coverage increases as the rate of mulch application increases. Adequate soil surface coverage is achieved in most instances with straw mulch applications of 1 to 2 tons per acre (EPA, 1976).

Reducing slope is another effective way of lowering water and soil loss. For example, with sandy clay loam spoil, sediment loss was reduced 65 percent under natural rainfall conditions when the slope gradient was reduced from 17.6 percent to 4.8 percent. However, potential major erosional losses from newly topsoiled areas still require management to minimize such losses through techniques such as mulching, until revegetation occurs and significantly reduces erosion (Gilley, 1980).

A sufficient depth of good topsoil provides most of the major needs for good plant growth and its availability is one of the most important factors in successful revegetation (Brundage, 1974). Topsoiling studies in North Dakota showed that over sodic spoils, 28 inches of subsoil material and eight inches of topsoil generally achieved 90 percent of the maximum vegetation yield occurring on similar soil types in the county (Schuman and Power, 1980). Increasing the topsoil depth to 24 inches seldom gave statistically significant higher yields. Where the covered material is not phytotoxic, a topsoil depth of nine inches may be acceptable. If topsoil can be transplanted with sods still intact, this speeds the process of revegetation, by introducing native plants immediately to the disturbed area (Hodder, 1977). Planning for topsoil utilization at active mines should insure that sufficient amounts are available. Moisture storage capacity of the surface layers can be increased by underlying the topsoil with a thick coarse-textured, buffer layer of rapidly-infiltrated soil material that will allow increased absorption of surface flow (Hodder, 1977).

If topsoil of suitable quality is in short supply, the available materials can be upgraded. Since nutrient deficiencies or toxicities of soil materials are highly site specific and variable, appropriate recommendations must be based on analysis of actual data. Fertilization is frequently required to raise levels of nitrogen (N), phosphorous (P), and potassium (K). For example, on a transitional sub-alpine site at 9,800 feet above MSL on the Beartooth Plateau, in southwestern Montana, the following soil amendments were used per acre: 600 lbs of 18-46-5 NPK fertilizer with 0.8 percent zinc, 2,000 lbs. of lime and 2,000 lbs. of dried steer manure (Brown and Johnston, 1978). These items were applied separately and uniformly to the experimental plot and mixed into the top six inches of spoil material with a toothed harrow. Two thousand pounds per acre of straw mulch were added to the surface to improve soil surface properties for plant establishment. The mulch was held in place with a water soluble asphalt emulsion. During the first growing season, an additional 100 lbs per acre of 27-0-0 fertilizer was added to insure adequate nitrogen (N) for initial growth. With these amendments, satisfactory vegetation establishment and growth were achieved and maintained (Brown, 1980).

At the Jim Bridger mine, in a six-inch precipitation zone near Green River, Wyoming, revegetation treatments were tested on stored and directly applied topsoil overlying minespoils. Researchers had considered a bare spoils revegetation treatment but observations indicated that revegetation was unsuccessful on untreated spoils (Green, Pentecost, and Taylor, 1978).

Four treatments were undertaken at the Jim Bridger mine and measurements were made of vegetation cover and production in 1976-1978. A seed mix was sown onto three treatment areas: directly-applied topsoil, stored topsoil, and mulched topsoil. The three treatments were applied over minespoils. Results were compared with adjacent undisturbed native revegetation areas. Ground cover averaged about 38 percent for the three topsoil treatments. Cover on the native area was only 25 percent. Standing crop biomass ranged from 200.6 g/m^2 to 404.3 g/m^2 in 1977 and 1978 on the three topsoil treatment areas. Insufficient data was available to detect significant differences between treatments. However, production on the native area was only 55 to 65 g/m^2 (Argonne National Laboratory, 1979).

In Casa Grande, Arizona, ASARCO has successfully revegetated copper mining tailings and dumps using intensive techniques. Dump slopes are capped with alluvium or conglomerate and finished to a 1.5:1 angle of repose. Drip irrigation systems are laid out across the slopes and a wide variety of desert shrubs and trees have been successfully grown without topsoil. Nursery grown stock is hand planted with slow release fertilizer tablets and adjacent to drip irrigation emitters (Thames, Verma, and LaFevers, 1977).

Numerous soil surface manipulations are available to enhance revegetation by increasing seed germination, seedling establishment percentages, and reducing soil erosion. Techniques include chiseling, surface and sub-surface ripping to reduce compaction, gouging, pitting, scarification, offset listering, and dozer basins (Hodder, 1977). Each procedure affects the soil surface in slightly different ways, tending to concentrate water in seeded sites, reduce salt concentration problems, create a surface texture beneficial to vegetation establishment, and restrict soil erosional movements to local areas. The most appropriate techniques to use will depend on the soil properties and characteristics of each site.

Chiseling, surface and sub-surface ripping are useful compaction reducing techniques where appropriate soil or spoil materials exist. Chiseling loosens spoil to a depth of six to eight inches and creates parallel surface furrows which slow water flow and increase infiltration. It is a favorable method of seed-bed preparation for broadcast planting (Hodder, 1977). Ripping accomplishes a similar purpose but also aerates the root zone. It is more expensive and requires more powerful equipment to loosen spoil to depths of two to four feet. This is important where deep, heavy compaction is encountered for deep rooting plants such as shrubs. Multishank ripping creates the most evenly ripped surface.

A widely-used surface pitting procedure forms contiguous surface basins about 10 inches deep, 18 inches across, and 25 inches long (Hodder, 1977). This configuration is best suited to gradual slopes and flat areas as atop Atlas' waste rock dumps. Pitting significantly reduces runoff from moderate intensity storms since all the contiguous "mini-basins" drain internally and retain water. This configuration is favorable for broadcast seeding since the upper edges of each berm will quickly erode and cover seed in the basin, enhancing germination (Hodder, 1976).

At Emery, Utah, simulated mine spoil revegetation tests have shown good vegetation establishment in a six inch rainfall zone on gouged surfaces, with grass hay mulch and broadcast seeding (Robert Ferguson, 1982, personal communication). This treatment was more effective in establishing vegetation than harrowing or mulching only.

Dozer basins are used on steeper terrain and accomplish a purpose similar to terracing, but with less cost. The basins are usually about two feet deep, fifteen feet long, four feet wide, and placed approximately along the contour at about thirty foot vertical intervals. Generally, basins collect enough water to thoroughly saturate the surface soil, so that good establishment of vegetation in the basin bottom is virtually assured in the first year. Well established plants will start spreading between basin interspaces the second year (Hodder, 1977).

Between rows of dozer basin benches, contour pitting or furrowing can be important to further reduce runoff. These techniques increase soil surface roughness, thereby increasing water and soil retention, and enhancing seed germination and establishment. Planting seeds in the bottom of deep furrows will improve vegetation establishment because of increased water collection by the furrow. With suitably textured subsoil, these techniques have been used for successful revegetation without topsoil (Hodder, 1976).

Placement of snow fences perpendicular to prevailing winds has increased snow deposition and springtime moisture infiltration in numerous areas. Comparing snowfenced and open (control) areas, numbers of seedlings established have been measured at two to ten times greater behind fences on non-reclaimed spoil banks of 3, 9, and 15 years age near Kemmerer, Wyoming. Certain plant species such as tall wheatgrass (Agropyron elongatum) form tall, resistant stalks which function effectively as small windbreaks. When established in rows, these plants function like snow fences and increase snow accumulations in the immediate area (Hodder, 1977).

The Department of Energy has considered several means of stabilizing inactive uranium mill tailings at Green River and Mexican Hat, Utah (Ford, Bacon & Davis, Utah, Inc. 1981 a,b). They considered:

- Chemical stabilization (treatment of the tailings surface)
- Volumetric chemical stabilization (solidifying the bulk of the tailings)
- Physical stabilization (emplacement of covers)
- Vegetative stabilization (establishment of plant growth)

They concluded all stabilization methods had disadvantages, but in low rainfall areas (less than 10 inches annually), vegetative stabilization methods would be unreliable. Although mill tailings are considerably different than waste rock spoil, their findings are relevant concerning the infeasibility of revegetation in arid areas.

2.4 VEGETATION SPECIES AND TECHNIQUES

Several workers have considered the characteristics of plants which are desirable to rehabilitate disturbed areas. Native species adapted to the climatic conditions of the site are frequently easily established, however, introduced species often show better potential for rehabilitating disturbances (Monsen, 1975). Mining operations frequently create such severe disturbances that few plants are well adapted to growth in these harsh, sterile or toxic, spoil-overburden materials. Consequently research programs have been undertaken by various agencies and individuals to determine which species are capable of growing on severe sites. Much of this research is applicable to sites being reclaimed by Atlas Minerals. Several good species have been found and propagation programs are underway in government and private nurseries. Species which are useful in arid and semi-arid sites similar to mine spoils include:

Kochia prostrata, a low shrub introduced from Russia
Linum lewisii, Lewis flax
Hedysarum boreale, Utah sweetvetch
Artemisia abrotanum, old-man wormwood

Purshia glandulosa, desert bitterbrush

Ephedra viridis, green ephedra

Agropyron intermedium, intermediate wheatgrass

Hassell (1977) indicates that plants suitable for colonizing mine wastes must be drought hardy and adapted to a wide range of soils. Land changes generally increase climatic extremes in relation to plant growth, requiring adaptable species. Two species which established well on copper mine tailings at the Cyprus Pima Mining Company in Tucson, Arizona, and which would be adapted to most of Atlas Minerals' sites are:

- Atriplex canescens, Four-wing saltbush. This plant established well and was very competitive in eliminating annual weeds such as Russian thistle. Rodents have encroached on revegetated areas but have not been a problem in maintaining stands of four-wing saltbush on tailings. Once established, it should require minimum care since it is a long-lived perennial.
- Atriplex semibaccata, Australian saltbush is adapted on areas which receive a minimum annual precipitation of 12 inches. In lower rainfall areas supplemental irrigation or planting in areas which receive runoff is required. Australian saltbush is a short-lived perennial (3 to 5 years), but reseeds readily. It provides a good lower cover on tailing slopes. It spreads about 1.5 feet in one year and responds very well to fertilizer. Australian saltbush has been established on soils with pH 8.2. Seeding rate should be 8 pounds per acre pure live seed with some adjustments for seeding method and seedbed condition. This shrub is moderately competitive with invading grasses and weeds. An established stand provides good cover.

For quick growth and stabilization of soils, annual grasses and cereal grains are quite useful. These domestic plants germinate quickly and easily under various conditions; they grow rapidly and seed is commercially available and inexpensive. Their establishment and growth reduces erosion on any areas which require temporary stabilization or initial revegetation prior to establishment of perennials. The fibrous, diffuse root systems of grasses are effective in binding soil and adding beneficial organic matter to the soil. High levels of production and cover were achieved on copper mine tailings in southern Arizona with fertilized and irrigated plantings of winter barley, annual rye, milo-maize, and Sudan grass. Effective erosion control was obtained within two weeks of planting. In one growing season, above ground production for the different species was from 394 to 2,088 lbs per acre; below ground production in the upper 35cm of tailings was from 1,215 to 5,722 lbs per acre; ground cover percentage of vegetation was between 64 and 89 percent (Ludeke, 1977). Other suitable "temporary" species include winter or spring wheat, speltz, and oats (Hodder, 1977). These easily-established plants upgrade soil properties, improving conditions for establishment and growth of perennial vegetation.

Hydromulching is especially useful on sites such as waste rock dumps, outer slopes and tailings embankments. However, in the arid climate of the Colorado Plateau, a three stage process of seed bed scarification, seed application, and mulch application would provide the best chance of successful revegetation using hydromulching on spoil materials. The organic additives hold seed and fertilizer in contact with the spoil so that vegetation establishment can take place on steep or inaccessible sites. Seed applied wet can germinate more rapidly, so that robust stands of vegetation may establish more quickly. Legume seeds can be spray-planted in an inoculating-pellet form with root-nodule bacteria which will enhance nitrogen fixation by plants when they become established (Kay, 1977). These organisms are not soil mycorrhiza. Mycorrhiza are generally difficult to establish in disturbed soils and are most frequently associated with tree roots.

In one demonstration, after 11 inches of rain, hydromulching on 1:1 slopes of decomposed granite, soil loss in an untreated area was estimated at 249 lbs per acre, but areas hydromulched with 1,000 to 3,000 lbs per acre of fiber lost only 8 to 26 lbs of soil per acre. Twelve to 18 seedlings were established per square foot on treated areas, versus none in the control (Kay, 1977).

On droughty or thin-soil sites, such as the rocky, steep slopes of the waste-rock dumps, containerized planting stock has advantages to insure vegetation establishment. Containerized plants will have higher percentages of stand success than for direct seeding, since mortality is avoided during the critical developmental stages of seed germination and establishment. On extremely severe sites, containerized stock is usually the best way to successfully establish vegetation. Quick plant establishment is assured since well developed plants are used. Container grown grasses can quickly establish an extensive ground cover since they are well-rooted and ready to spread when planted. The main disadvantages of containerized plants are that they are heavier to transport, require daily attention prior to planting, and are generally more expensive than other vegetation materials (USDA Forest Service, 1979), although the latter may not be true for successful revegetation on harsh sites.

Working in the arid (6" annual rainfall) salt desert shrub zone in Utah, several workers (VanEpps and McKell, 1980; McKell, et. al., 1979) have shown better revegetation success using transplants than seeding. Under such arid conditions, transplanting of well-developed plants may be more successful than direct seeding and hoping for rain. The best planned seedings will sometimes be unsuccessful due to unfavorable weather conditions. Transplants of species native to the site can be successful in average or above average precipitation years without irrigation. However, in drought years, a modest level of irrigation will be required to insure survival during the initial years after planting. Data from these studies suggest that plantings need to be observed for a minimum of 3 to 4 years before concluding plants are in a permanent survival condition. Mortality of transplants is usually high (up to 60-70%) under harsh conditions of the salt desert zone. However, mortality rates diminish rapidly within 2 to 3 years. In the higher elevation pinyon-juniper zone, high percentages of transplants will survive.

A variety of techniques are available for growing and propagating transplants. Greenhouse grown grass plugs are a particularly good idea for establishing warm season grasses such as alkali sacaton, blue grama, galleta, and sand dropseed. In dry climates during the spring season, by the time temperatures are warm enough to allow seed germination, the soil is too dry to allow germination (Robert Ferguson, personal communication, 1982). When planted, the plugs will frequently survive and grow well.

To test the growth supporting capabilities of geologic materials in the Henry Mountains coal field in southern Utah (south of Hanksville), sandstone, gray shale and saline sandstone materials from rock outcrops were crushed and the rock materials were prepared for planting (McKell, VanEpps, and Richardson, 1979). Twenty four months after transplanting, the following survival percentages were achieved on the geologic materials: 92 percent on sandstone; 76.4 percent on gray shale; and 95 percent on saline sandstone. Plants tested included fourwing saltbush, shadscale, cuneate saltbush, indian ricegrass, and russian wildrye.

Overburden or geologic materials were considered acceptable as plant growth media if they met the following criteria:

- water soluble boron content <1 ppm
- EC of saturated extract <4.0 mmhos/cm
- pH of saturated paste between 7.0 and 8.5
- stone and gravel (>2.0mm diameter) less than 15% of volume percent

They indicated revegetation was difficult on these dry, inhospitable sites, but it could be accomplished using appropriate species and procedures.

In moist areas of Tennessee, growth rates for loblolly pine seedlings have been greatly increased through use of slow-release fertilizer tablets (Berry, 1979). Survival was not affected by use of the tablets, but on nutrient-deficient mine spoils, after three years growth, fertilized trees had up to 20 times more volume than unfertilized trees. In the more arid Utah climate, results would be expected to be significant for pinyon-juniper trees, though less dramatic than in a wetter climate.

Regarding time for seeding, most workers feel areas which receive significant snowfall should be planted in late fall (Brown, et. al., 1978). Planting should occur after daily temperatures are sufficiently low so that no germination or release from dormancy will occur. Usually during early spring runoff, the wet soil surface is not suited for planting. Fall planting enables seeds to remain undisturbed and take full advantage of moist spring conditions for germination and establishment. However, transplants should be placed in early spring to avoid frost heave of soil which might occur in winter (McKell, VanEpps, and Richardson, 1979). Frischknecht and Ferguson (1979) found on arid oil shale lands in eastern Utah, if fall seedings sometimes failed, spring planting of container-grown plants was frequently successful.

2.5 RECLAMATION PROCEDURES AT OTHER URANIUM MINES

Some information was gathered on actual operational procedures currently in use, or research procedures being conducted at other uranium mines. Information was gathered primarily on three mine sites: Anaconda's Jackpile-Paguate mine near Grants, New Mexico; Union Carbide operations at Uravan, Colorado; and Homestake Mining's Pitch Project near Gunnison, Colorado. The level of reclamation effort required at different mine sites seems to vary with the size of the mine operation, and from state to state, dependent on the regulatory climate.

Reclamation is a major, ongoing project at the Jackpile Mine (Reynolds, Cwik, and Kelley, 1978; Reynolds, Kelley, and Cwik, 1978) and revegetation has been successful on overburden. Several types of overburden are available for use in revegetation at this large open-pit mine but the Tres Hermanos sandstone has been shown to have superior revegetation properties to the Dakota and Jackpile stratigraphic members. Tres Hermanos soil had more favorable nutrient properties and better cation exchange capacity than the other materials. A specialized piece of crushing equipment was used to produce a sufficiently fine textured soil-like material for revegetation. Four D-9 Caterpillars were used to work the material down and clear away the very large boulders. A 44-ton Caterpillar compactor model 825-B was driven over the surface to further crush broken boulders and slabs creating a soil like texture. The compactor tracks left a pock-marked surface configuration which helped collect water and retard erosion while enhancing vegetation establishment. The procedures were cost effective and resulted in costs considerably lower than the initial reclamation cost estimate.

A seed mixture of nine grasses native to the region were drill seeded in July, 1976, to take advantage of summer rains. Plant species and proportions in the seed mixture which was used in their 12-inch annual precipitation zone were:

Genus and Species	Common Name	% of Mixture By Weight
Bouteloua gracilis	blue grama (Lovington)	30
Sporobolus cryptandrus	sand dropseed	15
Bouteloua curtipendula	sideoats grama (Vaughn)	4
Sporobolus airoides	alkali sacation	5
Oryzopsis hymenoides	indian ricegrass (Paloma)	5
Eragrostis curvula	weeping lovegrass	10
Andropogon scoparius	little bluestem (Pastura)	15
Agropyron smithii	western wheatgrass	5
Andropogon hallii	sand bluestem	6
Melilotus officinalis	sweetclover	5

Seeding was followed by mulching with barley straw and crimping. Fertilizer was not added until the following summer. In the fall, density of planted species averaged 36.5 plants per square meter. Subsequent observations have shown maintenance of satisfactory vegetation densities on the reclaimed areas.

Revegetation research conducted by the Bureau of Mines at Uravan, Colorado, has shown good revegetation success with intensive techniques and moderate success with less intensive techniques (Froisland, Placek, and Shirts, 1982). They covered a uranium tailings dump on a 32° northeast facing slope with a 6" thick layer of uranium mine waste rock. Size distribution of the material varied from greater than 2" to passing a 65 mesh screen. Electrical conductivity of the material was 2.2 mmhos/cm and pH was 7.6. They had best revegetation results (240 plants per square foot) with crested wheatgrass which was fertilized with sewage sludge and sprinkler irrigated. A section which was fertilized, but not irrigated, developed 3.1 crested wheatgrass plants per square foot and 24 percent ground coverage. Crested wheatgrass established well when planted in May, 1976, and better than indian ricegrass. 'Tegmar' intermediate wheatgrass also developed ground cover percentages comparable to crested wheatgrass seedings. It has the extra advantage of being rhizomatous so it can spread vegetatively.

Mr. Phil Barnes, reclamation specialist for Homestake Mining's Pitch Project open pit uranium mine near Gunnison, Colorado, was contacted concerning reclamation practices they currently use. For roadcuts and fills they hydromulch with approximately 2,000 lbs/acre of Conwed 2000, applied in a two step operation with seed first and mulch/fertilizer in the second application. They use approximately 300 bulk pounds per acre of 18-25-12 (NPK) fertilizer. Slopes are at about 35° to 37° and revegetation success has been good, sowing approximately 50 lbs/acre of domestic types of grasses, forbs and legumes such as red fescue, meadow foxtail, and timothy. On overburden dumps they have revegetated directly in spoil materials, mulching with 3 to 4 tons per acre of native grass hay. The hay is deep disked into the overburden material to a depth of about 6 to 8 inches. Maintenance fertilization has been used annually for several years with an 18-46-0 (NPK) mix.

3.0 CATEGORIZATION OF MINE SITES

Pertinent revegetation information for the Atlas mine sites in Colorado and Utah was gathered and summarized in Tables 3.1 and 3.2. This information can be used to assess factors that differ between mine sites and which will influence revegetation procedures and potential success. Sources for this information included Atlas Minerals mine site location maps; site specific spoils analysis; rainfall data from NOAA, U.S. Department of Commerce, Climates of the States; the Bureau of Land Management seed lists, the site visit, and other information received from Atlas Minerals. Applicable information that was available or could be reasonably interpolated was placed on these tables.

Vegetation types were divided into three groups with utilization of the U.S. Bureau of Land Management Field Guide to Seed Lists for San Juan and Grand County, Utah, to determine the division between lower and upper Pinyon-Juniper types. Below 6,000' was considered lower Pinyon-Juniper and above 6,000' was considered upper Pinyon-Juniper. The mine sites around the Green River area were classified as being in the Salt Desert-Shrubland vegetation type.

Revegetation success potential is based on elevation, rainfall, spoil materials characteristics, and vegetation type. Sites situated in the upper Pinyon-Juniper type, above 6,000' to 7,300' in elevation, with a minimum of 12 inches of annual rainfall were given a good revegetation success potential. Sites that were located in the lower Pinyon-Juniper type, located from 4,800' to 6,000' in elevation, with a range of 9-14 inches of annual rainfall, were given a fair to poor revegetation success potential. Sites located in the Salt Desert-Shrubland type were considered to have poor revegetation success potential.

Major revegetation limiting factors emphasized were aridity, where annual rainfall is below 11 inches, and spoil material problems. Spoil analyses could only be evaluated for those mine sites for which chemical data was provided. Information was not available for columns which were left blank.

Table 3.1

CATEGORIZATION OF UTAH MINE SITES

Utah Mines	Elevation	Location	Spoil Analysis pH	EC_e	SAR	Annual Rainfall[1] (inches)	Parent Material[3] Coarse Sandy	Sandy Loamy	Sandy Clayey	Vegetation Type[2]	Permit Area (Acres)	Revegetation Success Potential	Major Revegetation Limiting Factors
Cactus Rat	5,150	T22SR22ES33				9-11				Lower Pinyon-Juniper	17.3	Fair-Poor	Aridity
Calliham & Sage	7,000	T32SR26ES33 T32SR26ES34				12-16	X	X		Upper Pinyon-Juniper	44.6	Good	
Cane Creek											6.1		
Dunn	6,800	T31SR25ES14				12-16			X	Upper Pinyon-Juniper	34.8	Good	
Far West	6,800	R24ES28	8.0	.38	17	12-16				Upper Pinyon-Juniper	22.8	Good	Spoil Material
Four Corners #2 and #6	4,460	T21SR14ES22	7.8	11.4	2.9	6-8	X			Salt Desert-Shrubland	34.0	Poor	Aridity, Spoil Material
Happy Jack						9-11				Lower Pinyon-Juniper	11.7	Fair-Poor	Aridity
Ivy	6,300	T30SR24ES10				12-16		X	X	Upper Pinyon-Juniper	3.6	Good	
Locust Spider	6,200	T32SR25ES5				12-16				Upper Pinyon-Juniper	0.8	Good	
Louise	6,600	T30SR24ES13				12-16				Upper Pinyon-Juniper	5.7	Good	
Pandora	7,000	T29SR25ES6	7.9	3.5	4.2	12-16	X			Upper Pinyon Juniper	14.6	Good	
Patti Ann	6,800	T29SR24ES27	8.0	4.7	17	12-16			X	Upper Pinyon-Juniper	9.4	Good	Spoil Material
Probe	4,480	T21SR14ES14				6-8	X			Salt Desert-Shrubland	10.6	Poor	Aridity
Radium King	5,300	T37SR15ES11				9-11				Lower Pinyon-Juniper	27.3	Fair	Aridity
Rim Columbus	7,050	T31SR25ES30	7.9	5.4	5	12-16	X	X		Upper Pinyon-Juniper	16.8	Good	Spoil Material
Snow	4,440	T21SR14ES22				6-8	X			Salt Desert-Shrubland	21.5	Poor	Aridity
Star[illegible]rd	6,600	T30SR24ES11				12-16				Upper Pinyon-Juniper	5.0	Good	
St[illegible]d #2	6,800	T30SR24ES2	8.6	11.8	43	12-16				Upper Pinyon-Juniper	5.8	Good	Spoil Material
Velvet	6,500	T31SR25ES3	8.3	3.6	18	12-16	X			Upper Pinyon-Juniper	21.9	Good	Spoil Material
Windfall	6,600	T31SR24ES27				12-16		X		Upper Pinyon Juniper	3.0	Good	
Wood	6,600	T31SR25ES1				12-16				Upper Pinyon-Juniper	8.8	Good	

[1] NOAA, U.S. Dept. of Commerce, 1974. Climates of the States, p. 921-934.
[2] Bureau of Land Management, Field Guide to Seed Lists, San Juan and Grand County, Utah. Describes upper and lower pinyon-juniper zones as from 6,000' to 7,300' and 4,800' to 6,000', respectively.
[3] From field observations.

Table 3.2

CATEGORIZATION OF COLORADO MINE SITES

olorado Mines	Elevation	Location	Spoil Analysis pH	EC$_e$	SAR	Annual Rainfall[1] (inches)	Parent Material[3] Coarse Sandy	Sandy Loamy	Sandy Clayey	Vegetation Type[2]	Permit Area (Acres)	Revegetation Success Potential	Major Revegetation Limiting Factors
pril	6,400	T45NR18WS9				14-18				Upper Pinyon-Juniper	3.0	Good	
alanity Mesa	6,600	T50NR18WS3				14-18		X		Upper Pinyon-Juniper	4.7	Good	
rrowhead #18	6,400	T50NR18WS10				14-18		X		Upper Pinyon-Juniper	5.0	Good	
rrowhead #34	6,600	T50NR18WS3				14-18		X		Upper Pinyon-Juniper	2.0	Good	
lackjack	7,000	T43NR19WS25				14-18				Upper Pinyon-Juniper	3.0	Good	
ob Falcon	7,000	T43NR19WS21				14-18				Upper Pinyon-Juniper	9.9	Good	
liffdweller	5,800	T45NR19WS3				11-14				Lower Pinyon-Juniper	6.4	Good	
irefly	7,050	T43NR19WS21				14-18				Upper Pinyon-Juniper	3.0	Good	
esa	6,200	T45NR17WS7				14-18	X		X	Upper Pinyon-Juniper	9.9	Good	
neral Channel #12	6,800	T50NR17WS7				14-18		X		Upper Pinyon-Juniper	2.0	Good	
neral Park	6,300	T46NR17WS34				14-18				Upper Pinyon-Juniper	5.3	Good	
tober	6,700	T50NR19WS4	8.0	5.5	11	14-18				Upper Pinyon-Juniper		Good	Spoil Material
anuts #1 & 2	6,300	T46NR17WS32				14-18	X			Upper Pinyon-Juniper	9.0	Good	
laney	7,100	T43NR19WS8 T43NR19WS9				14-18				Upper Pinyon-Juniper	4.8	Good	
d Flag	6,100	T45NR18WS4				14-18				Upper Pinyon-Juniper	1.9	Good	
osevelt	5,700	T45NR19WS3				11-14				Lower Pinyon-Juniper	2.3	Good	
n Miguel	7,000	T43NR19WS8				14-18				Upper Pinyon-Juniper	3.6	Good	
smo	6,800	T47NR18WS24				14-18				Upper Pinyon-Juniper	2.9	Good	
arlight #7	6,100	T45NR18WS4				14-18				Upper Pinyon-Juniper	3.7	Good	
rawberry Roan	6,750	T43NR19WS32				14-18				Upper Pinyon-Juniper	2.7	Good	
[illegible]21	7,200	T43NR19WS25				14-18				Upper Pinyon-Juniper	5.2	Good	

OAA, U.S. Dept. of Commerce, 1974. Climates of the States, p. 595-613.
ureau of Land Management, Field Guide to Seed Lists, San Juan and Grand County, Utah. Describes upper nd lower pinyon-juniper zones as from 6,000' to 7,300' and 4,800' to 6,000', respectively.
rom field observations.

4.0 RECLAMATION METHODOLOGY AND COST ESTIMATES

4.1 INTRODUCTION

Revegetation and rehabilitation of severely disturbed sites as a result of mining, road construction, right-of-way development, and severe erosion from flooding, overgrazing, range fires, and other major disturbances have been the topic of research for many years. As a result of these disturbed, unstable conditions the potential for erosion from wind and water is very high and may result in degradation of the ecologic and hydrologic regimes. In an effort to stabilize the soil and prevent erosion, several methods (chemical, physical, vegetative, and a combination thereof) have been developed to stabilize disturbed sites.

As with most reclamation and revegetation attempts in the Western U.S., particularly in the southwest, moisture is usually the major limiting factor preventing establishment of a good, diverse vegetative cover. The application or implementation of specific reclamation techniques and treatments discussed here is an effort to maximize the natural climatic, soil, and vegetation conditions to develop an effective, erosion-resistant vegetative cover for Atlas Minerals uranium mine sites. This reclamation methodology has taken into account such topics as revegetation potential, land use prior to disturbance, and postmining land use which includes, but is not limited to, livestock grazing, wildlife forage and habitat, hunting, and off-road vehicle use.

The following procedures are described as a general methodology for reclamation and revegetation of the majority of Atlas' mine sites in Utah and Colorado. The procedures are described in the order in which they would be implemented on the mine sites and are recommended as a level of effort which, when implemented, should produce acceptable revegetation. For those sites where revegetation is not considered feasible, alternative procedures are recommended.

4.2 SITE PREPARATION

4.2.1 Trash Removal

Before major grading and recontouring activities can begin, all trash and solid waste debris must be buried or removed from the site. This includes pieces of old equipment that have been scrapped, buildings that are not of any use, old tires, and pieces of wood and steel that would interfere with the reclamation activities. The smaller items could be buried during the regrading of the slopes. The larger items should be hauled to an approved sanitary landfill.

4.2.2 Topsoil Salvage

Revegetation potential of most disturbed lands will be greatly enhanced by the salvage and redistribution of topsoil. Topsoil salvage for most of these sites was not undertaken, therefore any topsoil that can be salvaged during the reclamation process will be of great value for revegetation. Topsoil will be salvaged only from areas that will be disturbed or covered up during the grading and recontouring of the waste disposal piles (Section 4.2.3) and other related activities.

In order to minimize costs and still be able to utilize the topsoil, the soils can be salvaged by grading or pushing the topsoil away from the disposal pile base using a dozer. By starting at the toe of the existing waste rock piles and pushing away from the pile, a topsoil stockpile can be developed around the edge of what will become the new recontoured disposal pile. Slope reduction of angle of repose dump slopes will cover new soil areas, unless the soil is first removed. This suggested handling method will eliminate the need for special equipment to salvage, stockpile and return the topsoil. Soil will remain at the immediate site for respreading when grading is completed. The cost for transporting, stockpiling and returning the topsoil to the disturbed sites will be eliminated.

M-K recommends that Atlas Minerals continue their practice of salvaging all available topsoil and stockpiling it for any sites that are now active or that will be active in the future. The cost of soil handling is far outweighed by the beneficial properties of soil to enhance revegetation.

4.2.3 Grading and Recontouring

Major objectives of grading and recontouring are to increase the potential for revegetation by improving the micro-climate of the area to be revegetated, and to create suitably contoured drainageways. Currently existing angle of repose slopes are too steep to allow for significant water infiltration, and as a result, erosion causes sedimentation into adjacent water courses, and revegetation potential is limited. By restructuring the surface of the waste pile to a lesser slope the potential for water to be utilized by vegetation is greatly increased and soil erosion is reduced. All slopes that can feasibly be graded will be reduced to at least a 3:1 (horizontal to vertical) slope. Resloping should be done in addition to other recommended revegetation procedures.

It may not always be practical or feasible to reduce slopes, or the benefit of regrading may be questionable because of climate and/or soils problems. In this case resloping may be eliminated and slope compaction or minimal recontouring may be sufficient to stabilize the site.

It is imperative that all natural stream channels and drainageways be cleared of all spoil, ore, waste, fill material, and debris before the operator abandons the site except where approved by the Division. This requirement is mandated in Rule M-10 part 8, Mined Land Reclamation, General Rules and Regulations of the State of Utah.

4.2.4 Contour Furrowing

If long slopes (100' or more) are developed as a result of reducing steep slopes there still will be potential for soil erosion. The frequency, duration and intensity of the precipitation and the slope steepness, length, and infiltration rate and texture of the soil all interact to determine the erosion potential. Reclamation activities or techniques can not change the precipitation factors or the soil composition but a simple mechanical technique of contour furrowing can reduce the length of slope thereby reducing the erosional force. The number and size of the furrows is primarily dependent upon the length of slope and precipitation. Shorter slopes will not allow water to move downhill as rapidly, therefore sediment load will be reduced.

An additional benefit of the furrow is that surface water is collected and concentrated in the trench, improving local conditions for plant growth. These furrow sites will be ideal for transplanting live sets of grasses and shrubs. This technique will help ensure that some species become quickly established, and will provide seed for adjacent areas.

4.2.5 Topsoil Replacement

In addition to having sufficient precipitation, the second most important limiting factor in achieving successful revegetation is availability of topsoil. As a general rule, topsoil salvaged for use during reclamation activities is better suited to vegetative growth than is overburden or waste rock material. Topsoil will generally increase the potential for revegetation because it has physical and chemical properties which are substantially better than overburden. Since soil conditions vary from one site to another, it is conceivable that some surface soils are not conducive to plant growth. To insure that the soils are suitable as a plant growth medium, they should be chemically analyzed for the following parameters:

- pH
- Electrical conductivity (EC_e)
- Sodium adsorption ratio (SAR)
- Cation exchange capacity (CEC)
- Texture

Spoil materials should also be analyzed for these parameters, as well as several major nutrient parameters. Nutrients are more likely to be lacking in waste rock materials than in surface soil. These parameters are:

- NO_3 (nitrate) form of nitrogen
- Phosphorus
- Potassium

Topsoil replacement will be conducted only on those sites for which topsoil has already been salvaged or can be salvaged during grading and recontouring activities. As there may not be sufficient quantities of topsoil to cover the entire site, priority should be placed on distribution of soils on the slopes, prior to placement on flat dump surfaces. When available, soil should be respread to a minimum depth of two inches. Respreading can be accomplished with a dozer or maintainer.

As discussed earlier, topsoil is expected to have a more rapid infiltration rate than the waste rock material and therefore a greater amount of precipitation will penetrate the soil, creating a better water reservoir for plant growth, and diminishing erosion. If the spoil surface becomes hard or compacted prior to topsoil placement, the soil should be ripped to prevent slippage of the topsoil over the spoil surface.

4.2.6 Equipment Requirements

Site Preparation

To remove all trash and debris from the site and prepare for grading activities, a front-end loader and dump truck may be utilized. A small 3-5 cubic yard front-end loader should be adequate for the volume of material to be handled.

Topsoil Removal

The front-end loader used for clean up or the dozer used in grading would be used for pushing topsoil. For major expansions or development of new sites where the topsoil must be placed into stockpiles, a self loading scraper or front-end loader with a dump truck would be appropriate.

Regrading and Recontouring

Since most of the sites are fairly small (5 acres or less), a Caterpillar D-6 to D-8 or equivalent dozer will be adequate for all regrading.

Topsoil Replacement

If available topsoil is in piles around the perimeter of the waste dump, a front-end loader or dozer can be used to respread it by pushing it up the slopes. If the topsoil is taken from a stockpile, the recommendation for handling is to use either a self-loading scraper or a dump truck and front-end loader. The scraper can respread the soil quite evenly, however if the truck/front-end loader combination is used, the soil will have to be spread after it is dumped in piles on the regraded area.

Contour Furrowing

A dozer equipped with an angle blade can be used to construct the contours on 3:1 slopes. A blade or contour plow on the back of a farm tractor could also be used very effectively to develop the contours. Contours should be placed at approximately 40' to 60' horizontal intervals down the length of the slope.

4.3 FINAL SEEDBED PREPARATION

Once regrading and recontouring have been completed, steps to final seedbed preparation will be taken. These steps include spoil/soil chemical analysis, ripping to loosen compacted spoil, fertilizing based on the chemical analysis, and discing or harrowing to prepare a proper seedbed.

A chemical analysis, as previously described, should be conducted so that fertilizer or other chemical requirements can be determined. The objective of fertilization will be to alleviate nutrient deficiencies of nitrogen, phosphorous, and potassium. Moderate fertility levels of these nutrients should be established, adequate to support rangeland type vegetation. Other factors that may inhibit or retard the establishment of vegetation can also be determined. Soil treatments can be developed to alleviate chemistry problems or it may be determined that revegetation of the site is not practical or economically feasible.

As the spoil piles or waste dumps are extremely heterogeneous, two composite samples per acre, should be taken to determine the chemical properties of the surface material. Results of analysis will allow formulation of necessary soil amendments, and perhaps locate and identify any toxic materials. The samples should be collected after the site has been regraded so that the surface rooting material will be sampled. The composite sample should be collected from at least four locations and from the upper eighteen inches of spoil. The composited sample should be mixed and subsampled for the actual analysis material. Should the analysis indicate the presence of toxic materials, then more specific sampling should be conducted to locate the undesirable material and allow it to be isolated.

Ripping will be conducted only on surfaces that have been severely compacted by equipment. Ripping will not be necessary on those areas which have been graded and recontoured. If the area has topsoil available it will be applied following ripping. The surface of the area should be sufficiently rough to prevent slippage of topsoil.

If chemical analysis indicates a need, fertilizer will be applied so that it can be incorporated into the upper 2 to 3 inches of soil by the discing operation. Discing will take place over the entire site.

4.3.1 Equipment Requirements

Ripping requirements are for a D-6 to D-8 or equivalent dozer, preferably with a multishanked ripper. This ripper will provide more uniform ripping of spoils surfaces. Discing will require an extra heavy-duty disc and tractor. Disc blades should be approximately 24" in diameter.

On small sites, fertilizer can be applied with a hand held, centrifugal spreader; on large sites, a tractor-drawn mechanical spreader would be most cost effective.

4.4 REVEGETATION

4.4.1 Plant Species Selection Criteria

The species selected to comprise the seed mixtures must be adapted to the climatic conditions, the rooting materials in which the plants will be growing, and the proposed post-mining land use. Species suggested in Section 4.4.3 are adapted to the local conditions.

Species selected for the LaSal/Monticello and Colorado sites are moderate to very drought tolerant, adapted to warm, arid climates and medium to coarse-textured soils. Species selected for the Green River/Fry Canyon sites are highly drought tolerant, adapted to hot climates and coarse textured soils with low water holding capacity.

Climatic Conditions

Because of the variation in climatic conditions and vegetation communities among the sites, two different seed mixes have been developed, for the following vegetation types:

- Pinyon-Juniper
- Salt desert shrub

The Pinyon-Juniper vegetation type has a fairly wide elevational range from approximately 5,100 to 7,500 feet. The seed mix for this vegetation type contains a variety of species, some of which grow best at the higher elevations and some which grow best at the lower elevations. However, some individuals of all species should germinate and grow at all of Atlas' sites (approximately 5,100 to 7,200' elevation range) within this vegetation type. The annual precipitation at Monticello and LaSal, Utah (U.S. Department of Commerce, 1974) is approximately 12 to 14 inches annually with a fairly even distribution averaging just over one inch per month. May and June are slightly dryer with 0.5 to 0.75 inches while July, August, September, and October average approximately 1.5 inches per month (Table 4.1). These long-term precipitation averages (1931-1955 data) are considered representative of current conditions, because they are based on such a long measurement period. Significant year-to-year precipitation changes have almost no effect on a 25 year average precipitation figure. These precipitation figures are considered to be representative of the Colorado mine sites as well as the Utah mine sites east of Moab and Monticello. The sites will have different amounts of precipitation but are considered sufficiently close to these long-term average figures for planning purposes.

The desert sites (Green River and Fry Canyon) are at an elevation of 4,400' to 5,300'. Precipitation amounts are low ranging from approximately 6 to 10 inches annually. This low rainfall makes the success of revegetation seedings unpredictable. The sites near Fry Canyon (Happy Jack and Radium King) are transitional from lower Pinyon-Juniper to the salt desert shrub zone and are considered difficult to revegetate.

Summer temperatures, especially for the Green River and Fry Canyon sites are quite high, often exceeding 90°F. The average monthly temperatures at Green River and Fry Canyon are given on Table 4.2. The long-term average temperatures should be representative of current conditions. The sites located between LaSal and Monticello, Utah, and sites in Colorado will not be subjected to quite as high temperatures although the summer months are fairly hot and dry. Because of the hotter temperatures and lower rainfall, revegetation at the Green River and Fry Canyon sites will be relatively difficult. Chances for successful revegetation are better at the other sites.

Soil Conditions

The waste rock spoil materials are not typical of normal soils due to lack of weathering and recent exposure to the elements.

Table 4.1

AVERAGE MONTHLY PRECIPITATION

Location	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Green River	0.37	0.38	0.46	0.44	0.36	0.52	0.54	0.81	0.53	0.68	0.35	0.47	5.91
La Sal	1.07	0.89	0.98	1.09	0.79	0.74	1.41	1.67	1.24	1.32	0.77	0.93	12.93
Moab	0.57	0.62	0.76	0.78	0.57	0.47	0.55	0.87	0.78	1.05	0.67	0.71	8.40
Monticello	1.10	0.92	1.04	0.91	0.78	0.63	1.38	2.0	1.47	1.63	0.80	1.15	13.81

Data Collection Period - 1931-1955
Locations are in the state of Utah

Source: National Oceonic and Atmospheric Administration (NOAA)
U.S. Department of Commerce - 1974
Climates of the States, pp. 921-934.

Table 4.2

AVERAGE MONTHLY TEMPERATURES

Location	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Average
Green River	22.7	32.0	42.7	53.7	63.0	71.5	79.8	77.1	67.7	54.0	37.5	28.2	52.5
Moab	29.7	36.5	46.1	56.7	65.4	73.8	80.7	77.6	69.4	56.8	41.6	33.0	55.6
Monticello	25.4	29.2	35.4	45.2	53.5	61.9	69.2	67.0	60.4	49.8	36.5	28.5	49.6

Data Collection Period - 1931-1955

Source: National Oceanic and Atmospheric Administration (NOAA)
U.S. Department of Commerce - 1974
Climates of the States, pp. 595-613.

Hand-texturing soils analysis done at Utah State University did not adequately determine the texture of the material (Table 4.3). The analyst's statement was that the material appeared to be a sandy loam, but with continuous rubbing between the fingertips, the particles broke down and washed away. This might indicate that currently sandy surface materials might weather relatively rapidly into finer-textured materials.

The spoils analysis data in Table 4.3 are from composited samples collected from dumps of several Atlas' mines. Basic agronomic parameters were analyzed. Problem areas are evident in several parameters and at several mines. Values for pH ranged from 7.8 to 8.6. These alkaline values are typical of arid western conditions and present few limitations to plant growth. Electrical conductivity (EC_e) values indicated generally saline spoil materials as values ranged from 0.38 to 11.4 mmhos/cm. Materials with EC_e above 4.0 are considered saline (Hausenbuiller, 1972) and 5 of 8 samples exceeded this value. High EC_e values reduce seed germination percentages, but in dry climates, little can be done to lower EC_e values.

Phosphorous values were low with only one sample, at 9 ppm, considered adequate. Fertilizer application can increase phosphorous availability. Potassium was generally adequate, as a level of 120 ppm is normally considered satisfactory for plant growth. Lime ($CaCO_3$) was readily available, corresponding to the alkaline nature of the soil. Nitrate (NO_3) nitrogen is readily taken up by plants and was abundantly found in these samples. The high values seem anomalous and are much higher than concentrations normally found in good agricultural soils. Perhaps ammonium nitrate (NH_4NO_3) residues, if used as a blasting material, might account for the high concentrations.

Sodium (Na) and calcium + magnesium (Ca+Mg) are utilized to compute SAR, the sodium adsorption ratio. Sodic soils have poor physical properties which inhibit vegetation establishment and growth. SAR's less than 8 create minimal problems for vegetation growth. Values

Table 4.3

RESULTS OF SOILS ANALYSES FROM SPOIL MATERIAL AT SEVERAL ATLAS MINE SITES[1]

Mine Site Name	Geologic Formation	pH	Electrical Conductivity EC_e (mmhos/cm)	Phosphorous P (ppm)	Potassium K (ppm)	Lime	Nitrate NO_3-N (ppm)	Sodium Na (meq/l)	Calcium Magnesium Ca + Mg (meq/l)	Sodium Adsorption Ratio SAR	Iron Fe (ppm)	Zinc Zn (ppm)	Texture
Standard II	Cutler	8.6	11.8	1.6	148	+	6.8	98.8	10.8	43	1.0	0.2	*
Far West	Chinle	8.0	0.38	0.8	320	+	401	24.1	4.1	17	1.5	0.6	*
October	Saltwash	8.0	5.5	9.0	171	+	165	30.7	14.8	11	9.7	10.0	*
Pandora	Saltwash	7.9	3.5	1.1	153	+	95	11.6	15.3	4.2	26.5	1.0	*
Patti-Ann	Chinle	8.0	4.7	1.3	265	++	24	37.7	9.9	17	3.4	1.6	*
Rim Columbus	Saltwash	7.9	5.4	1.8	90	+	95	22.4	39.8	5.0	8.9	0.5	*
Velvet	Chinle	8.3	3.6	1.7	102	+	49	29.7	5.6	18	3.0	0.5	*
Green River #2	Saltwash	7.8	11.4	2.6	81	+	390	22.0	113	2.9	2.4	1.3	*

[1] Samples were composited, collected and combined from several dump locations at each mine site.

*Non typical Soil. Would appear to be Sandy Loam. However, continued rubbing with fingers, particles break down and seem to wash away.

between 8 and 15 are considered sodic, with significant limitations on plant growth. Values exceeding 15 create severe problems for plant growth. The data in Table 4.3 indicate that three samples showed no sodium problems (SAR<8), while one sample was sodic and four samples were severly sodium affected (SAR>15). Severely affected spoil materials will require amendments with gypsum to diminish the sodium problem. Values for iron and zinc were not limiting to plant growth.

Due to the high variability in sample results, it is recommended that this group of chemical analyses be undertaken for all spoil materials to help formulate necessary chemical amendments to enhance revegetation. No apparent correlation was found between chemistry and geologic formation from which the spoil materials were taken. The tremendous diversity of geologic materials makes it seem unlikely that a particular formation would have uniform properties affecting revegetation.

Post Mining Land Use

A wide variety of native and introduced plant species will be utilized to help reestablish the proposed post mining land use of livestock grazing and wildlife habitat. Deep-rooted shrubs as well as fibrous rooted bunchgrasses, sodformers, and shallow rooted plants have been selected. Grasses, forbs, and shrubs, emphasizing native species, were chosen to provide a diversity which will in turn promote revegetation and site stabilization. Species have been selected which will support the grazing and browsing pressures of livestock and wildlife. An attempt has also been made to include species which will provide habitat for both game and non-game species of wildlife.

4.4.2 Seeding and Planting

Eventually, natural successional processes would revegetate most sites. However, the process is slow in arid climates, and erosional losses can be severe before revegetation is accomplished. By selecting adapted plant species and propagating them with appropriate techniques, stabilization can be much more rapidly accomplished. The following sections describe suitable seeding techniques and equipment.

Drill Seeding

After grading and recontouring the site a seed drill can be used to plant the seed. The advantages of drill seeding are:

- Regulated seeding rate
- Proper seeding depth
- Proper seed cover with soil
- A good firm seed/soil contact
- Protection of seed loss to birds, animals, insects, and weather

Physical properties of spoil and the placement of seeds are greatly improved if the surface is properly prepared and the seed drill is properly used.

A seed drill is considered cost effective whenever the site is large enough to warrant the use of a drill and if the surface conditions are not too rough to prevent its use. Broadcast seeding requires using twice as much seed per acre as does drill seeding. When more than a few acres are being reclaimed, the cost of seed drilling is usually less per acre than the costs of purchasing twice as much seed. Seed will be drilled at a rate of approximately 30 live seeds per square foot. It is probable that some of the sites will have an extremely rocky surface. In this case, damage to the seed drill may occur and broadcast seeding should be used. In addition to rough surface conditions, small sites, or slopes steeper than 3:1 are not suitable for drill seeding. The following techniques are proposed as alternatives to drill seeding.

Broadcast and Hydroseeding

These techniques are used on surfaces that are not conducive to drill seeding or, for broadcast seeding, when the site is too small to warrant utilizing a drill. The major disadvantage of these techniques is that the seed is generally left on the soil surface, rather than covered, and can readily dry out once it becomes wet.

Broadcast seeding, followed by harrowing or dragging to roughen the surface and cover seed, is a suitable alternative to drill seeding on small sites or when the surface is too rocky to drill. Hydroseeding can be effective on angle of repose slopes on canyon sidewalls. Hydroseeding is recommended as the best technique for steep slopes where other methods cannot be used. It is more expensive but is a practical technique. It may be difficult to locate contractors in the Moab area. The limited need for its use and the water needed for application also make it less attractive. Seed should be broadcast or hydroseeded at a rate of about 60 live seeds per square foot.

Transplanting

Germination and establishment are typically the most critical phases of plant growth. If there are special critical areas that need immediate protection, the use of transplants is recommended. This technique helps insure the establishment of vegetation since it bypasses the high mortality germination and establishment phases. Deep-rooting transplants of shrubs, and fibrous, spreading grass roots provide rapid soil stabilization. If transplanting is conducted in early spring during optimum soil moisture conditions, percentage survival should make transplanting effective.

For those sites that will not be recontoured or have fairly steep slopes or critically unstable areas such as near drainage channels or excessively erosive areas, transplants of grasses and shrubs should be utilized to help stabilize the soil. The early establishment of these species will also provide for an additional seed source to colonize the site. Utilizing transplants in conjunction with contour furrowing will improve the stability of the slope. Planting in the furrow is advantageous because of the increased amount of water which collects here. Rapid establishment and growth should be obtained.

The species that are recommended for transplanting are indicated on Table 4.4 and 4.5 for the respective sites. Shrubs should be planted at a rate of approximately one plant per square yard (9 sq. ft.) for general plantings and twice that rate for critical or special areas. For planting in a contour furrow, a spacing of 4 to 6 feet between shrubs or 1 to 2 feet for grass plugs, depending upon the species, should be a guideline. Grass plugs over larger areas should be planted at a rate of 4 plugs per square meter.

Bare-root, rather than containerized, shrub transplant stock is recommended due to lower unit costs, ease of planting and handling in the field. Survival rates may be lower than with container stock, but this is more than made up for by the lower unit purchase and planting costs. Bare-root seedlings are available from several Utah and Colorado suppliers. Small grass plugs are planted with the soil materials in which they are grown. If abundant, shrub seedlings may be transplanted from adjacent undisturbed areas of natural vegetation.

Bare-root seedlings must be transplanted when they are dormant. Optimum transplanting time is in early spring (February - March) when soil moisture is high, temperatures are cool, and consequently transpiration rates are lower. Transplanting is only recommended for contour furrows and localized critical areas. It is not recommended for large areas of each site.

Equipment

The equipment necessary for drill seeding will be a farm tractor and seed drill. For broadcast seeding a mechanical spreader or a hand held cyclone spreader will be sufficient. If hydroseeding is selected a hydroseeder with a large volume capacity or a water truck may be needed because of the remoteness of the sites. Hand planting tools (planting bars, trowels, shovels) are satisfactory for transplanting bare-root stock and grass plugs.

4.4.3 Seed Mixture

Because of differences in climatic conditions and elevation, two different seed mixes have been developed. The Pinyon-Juniper vegetation sites at an elevation of 5,400' to 7,300' and with an annual precipitation rate of 12" to 18" will be reseeded with the seed mixture listed in Table 4.4. This mixture utilizes some additional species which require more moisture than do the species used in the Salt Desert Shrub seed mixture listed in Table 4.5. The species in Table 4.5 are very drought tolerant and are adapted to dryer more saline conditions, particularly the shrubs. The seed mix listed in Table 4.4 should be used at all mine sites except those in the vicinity of Green River, Fry Canyon, and the Cactus Rat site. The seed mix in Table 4.5 should be used at these lower sites, in the salt desert shrub vegetation type and at the lower limit of the Pinyon-Juniper zone.

These seed mixtures utilize species which are generally available. Since some seeds are collected by hand from native stands, in some years not all these species may be readily available. In this instance, these species may be deleted from the seed mix. Seed costs are relatively insignificant in relationship to total reclamation costs and the selection of adapted species should not be comprised to realize modest cost savings.

Species considered least essential, and which could be most easily omitted are:

Table 4.4	Table 4.5
Bottlebrush squirreltail	Galleta
Blue grama	Kochia prostrata
Mountain Mahogany	Greenes Rabbitbrush
Gooseberry leaf globemallow	

The seeding rates were based on drill seeding thirty seeds per square foot, which is equivalent to 12.2 lbs/acre for the Pinyon-Juniper mix and 7.9 lbs/acre for the salt desert shrub mixture. The current average seed cost per acre for these seed mixes is approximately $155 for the Pinyon-Juniper mix and $138 for the salt desert shrub mix, for drill seeding. Broadcast seeding costs would be twice as much.

Table 4.4

PINYON-JUNIPER VEGETATION TYPE
SEED MIXTURE

Plant Species	Scientific Name	% In Mix (seed numbers)	Seeds/lb.	Seeds/A	lbs/A (PLS)[1]
Grasses					
Indian ricegrass[3]	*Oryzopsis hymenoides*	10	188,000	130,680	0.7
Alkali sacaton[3]	*Sporobolus airoides*	10	1,750,000	130,680	0.1
Bottlebrush squirreltail	*Sitanion hystrix*	10	192,000	130,680	0.7
Crested wheatgrass	*Agropyron cristatum* (Nordan)	10	200,000	130,680	0.7
Intermediate wheatgrass	*Agropyron intermedium* (Tegmar)	10	93,000	130,680	1.4
Russian wildrye	*Elymus junceus*	10	175,000	130,680	0.7
Blue grama[3]	*Bouteloua gracilis*	10	711,000	130,680	0.2
Shrubs[3]					
Fourwing saltbush	*Atriplex canescens*	3	52,000	39,200	0.8
Rubber rabbitbrush	*Chrysothamnus nauseosus*	3	335,000	39,200	0.1
Mountain mahogany	*Cercocarpus montanus*	3	59,000	39,200	0.6
Antelope bitterbrush	*Purshia tridentata*	3	15,000	39,200	2.6
Oakbrush sumac	*Rhus trilobata*	3	20,000	39,200	2.0
Forbs					
Gooseberry leaf globemallow[2]	*Sphaeralcea grossulariaefolia*	3	220,000	39,200	0.2
Yellow sweetclover	*Melilotus officinalis*	5	260,000	65,340	0.3
Utah Sweetvetch	*Hedysarum boreale*	4	145,000	52,270	0.4
Small burnet	*Sanguisorba minor*	3	55,000	39,200	0.7
				TOTAL	12.2 lbs.

[1] lbs/A expressed as Pure Live Seed (PLS) to achieve seeding rates of 30 seeds per ft^2 (drill seeding).
[2] Seeds per pound were estimated by comparison with other species of known seed weight.
[3] Species recommended to be transplanted if determined to be necessary.

Table 4.5

SALT DESERT SHRUB VEGETATION TYPE
SEED MIXTURE

Plant Species	Scientific Name	% In Mix (seed numbers)	Seeds/lb.	Seeds/A	lbs/A (PLS)[1]
Grasses					
Galleta	Hilaria jamesii	12	159,000	156,816	1.00
Alkali sacaton	Sporobolus airoides[3]	15	1,750,000	196,000	0.10
Indian ricegrass	Oryzopsis hymenoides[3]	13	118,000	169,900	0.9
Sand dropseed	Sporobolus cryptandrus[3]	12	5,000,000	156,800	0.03
Crested wheatgrass	Agropyron cristatum (Nordan)	14	175,000	183,000	1.00
Shrubs[3]					
Kochia prostrata	Kochia prostrata	5	480,000	65,340	0.14
Shadscale	Atriplex confertifolia	5	64,900	65,340	1.00
Douglas Rabbitbrush	Chrysothamnus viscidiflorus	5	750,000	65,340	0.1
Greenes Rabbitbrush[2]	Chrysothamnus greenei	5	750,000	65,340	0.1
Atriplex obovata[2]	Atriplex obovata	3	25,000	39,200	1.6
Mat saltbush	Atriplex corrugata	3	60,000	39,200	0.7
Fourwing saltbush	Atriplex canescens	3	52,000	39,200	0.8
Forbs					
Gooseberryleaf globemallow[2]	Sphaeralcea grossulariaefolia	4	500,000	52,272	0.1
Yellow sweetclover	Melilotus officinalis	5	260,000	65,340	0.3
				TOTAL	7.9

[1] lbs/A expressed as Pure Live Seed (PLS) to achieve seeding rates of 30 seeds per ft^2 (drill seeding).
[2] Seeds per pound were estimated by comparison with other species of known seed weight.
[3] Species recommended to be transplanted if determined to be necessary.

To be successful, seeding must take place at the appropriate time of year. The seeds must be in the soil when moisture and temperature conditions are optimum for germination and growth. For this reason a late fall planting (late October through November) is recommended. The seeding should come after a hard killing frost, when temperatures are not warm enough to induce germination, but before heavy snow fall. Seeding at this time will minimize the likelihood of late fall germination. By planting in late fall, the seeds will already be in the ground when spring snowmelt and warming starts. The warm season grasses, particularly for the salt desert shrub sites, may be difficult to establish because by the time temperatures are warm enough to encourage germination, moisture conditions are fairly dry. Germination of warm season grasses may be relatively unsuccessful at elevations of about 5,200' or less. The Pinyon-Juniper sites have a fairly even distribution of moisture throughout the year, and germination establishment should be reliable.

4.5 MULCHING

The application of mulch on newly seeded sites serves several purposes. The mulch is primarily applied to stabilize the soil until vegetation becomes established. Additionally, on sites with soils that tend to crust on the surface, the mulch diminishes or prevents crust formation. This softening and enhancement of the soil surface will enable seed to germinate and emerge more easily. It may mean the difference between adequate vegetation establishment and none at all. Mulch also adds organic matter which improves soil structure and tilth, in turn increasing infiltration rate and water holding capacity of the soil. Mulching reduces soil surface temperatures, thereby reducing water loss from the soil profile.

M-K recommends the use of grass hay mulch rather than cereal grain straw because the grass hay is less fibrous, softer, less brittle, and can be more effectively crimped into the soil. Grain straw usually has a large amount of cereal seed in it which germinates and competes with the desirable species. It has also been suggested, although no data exists to support the claim, that the decomposition of grass hay will not tie up as much soil nitrogen as does the decomposition of cereal grain straw. If this is the case, then the amount of nitrogen fertilizer application can be more beneficial to vegetation growth.

4.5.1 Application Rate

Grass hay or cereal straw should be applied at the rate of approximately 2 tons of mulch per acre. Slopes and critical areas should receive approximately 2.5 tons per acre to help insure proper cover and reduce erosion potential.

Hydromulch, such as Conwed 2000, is a specially prepared mulch fiber applied via a water spray. It should be applied at the rate of approximately 1,500 lbs. per acre. Care must be taken to insure an even distribution of hydromulch. In most climates it has been suggested that hydroseeding and hydromulching be conducted in a one step operation. The equipment is capable of applying both mulch, seed, and fertilizer at one time. However it is M-K's recommendation that seed and mulch be applied in two separate steps. The fertilizer can also be applied with the mulch. If seeding and mulching are conducted in one step, much of the seed may end up on top of the mulch or in the mulch and does not establish contact with the soil. In arid climates this causes the seed to dry out faster, which inhibits germination and may eventually cause death from dessication. If the seed germinates, root development begins in the mulch instead of the soil. The rootlet has to grow through the mulch to reach mineral soil and establish normal root functions of water and nutrient uptake.

4.5.2 Crimping or Anchoring

After applying mulch it should be crimped or anchored to the soil. The crimping implement utilizes straight, flat discs with very dull edges to punch the mulch into the soil and prevent it from blowing away. This action reduces mulch and soil blowing and water movement over the soil surface, consequently reducing erosion. Other types of anchoring such

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as petroleum emulsions, asphalt tackifiers or netting are available, however they are more expensive than crimping and are not considered as effective.

If seeding is undertaken without mulching, problems may result on all but the most coarse-textured surface materials. These problems inhibit seedling germination and establishment and include crusting and compaction of the soil surface, erosional rill formation, dust blowing and slow water infiltration. These problems can prevent establishment of a good stand of vegetation.

4.5.3 Alternative Forms of Mulch

There are other types of mulches that may be considered. Because of various problems such as adequate supply, local availability, ease of transportation and handling, and the method of application, these forms are not recommended. Listed below are a few types of mulches which might be considered. However, M-K recommends native grass hay as the most suitable material.

- Bark chips
- Fiber netting
- Sewage sludge
- Gravel

4.5.4 Equipment

For mulching with grass hay, a power mulcher, which chops and blows the mulch on the area is most cost effective. This mulcher should be available through a contractor and may either be mounted on a truck or on its own axle pulled by a truck or tractor. A truck or trailer will be needed to haul the baled grass hay. After the mulch has been applied a crimper pulled by a farm tractor will anchor the material. For small sites (less than one acre), where it would be impractical to use mechanized equipment, the mulch can be spread by hand. This process is very slow, time consuming, and highly labor intensive.

For hydromulching and hydroseeding, a large volume pressurized water spray gun and tank will be used. A special mulch product developed for this process must be used.

4.6 WEED CONTROL

The treatments and techniques recommended thus far are designed to give the young seedlings a good chance for establishment and survival. If competition from weedy species is so great as to threaten the potential for good growth and establishment of seeded species, then competition should be reduced. Control of competition will make more moisture, light, nutrients, and space available to the desirable species which will in turn help produce a plant community with better vigor, productivity, and chances for long-term survival.

Weed control is expensive and therefore should only be undertaken when competition is severe and likely to significantly reduce growth of seeded species. A light infestation of weeds is not detrimental since it supplies some cover and shade for the seedlings and soil, and adds organic matter to the soil when weeds die.

4.6.1 Methods and Equipment

Weed control will be done either by mechanical means or with herbicides. Mechanical control consists of chopping or mowing the vegetation. A farm type tractor can be used to pull a rotary chopper or mower. This system is non-selective and cuts both desirable and weedy species. Mowing height should be 2 to 4 inches above ground. Herbicides can be used for comprehensive or selective weed control. A tractor mounted sprayer may be used for large areas or a hand held sprayer may be used if infestations are localized.

It is not anticipated that weed control will be necessary due to the relatively arid climate. However should moisture conditions become optimum, weed control may be necessary.

4.7 MAINTENANCE RESEEDING AND FERTILIZING

4.7.1 Methods

Depending upon the success of the initial seeding, certain areas may require reseeding if vegetation does not successfully establish. If there are only spotty bare areas, then the reseeding may be done most effectively by hand broadcasting to prevent damage to established vegetation, especially shrubs. If the whole area is poorly vegetated, then the seed drill may be most effective. Before considering reseeding on a large scale, the factors which may have caused failure of the previous seeding should be evaluated. Site specific spoil conditions should be reexamined. In arid climates, drought years can occasionally cause complete failures of numerous properly planned seedings. Climatic conditions at Green River and Fry Canyon are relatively inhospitable to seeding so that additional consideration might be given to the use of transplants.

Nitrogen fertilizer is water soluble and is therefore deficient in most soils unless there are plants growing that are taking nitrogen up or are capable of fixing atmospheric nitrogen into a form usable by other plants.

Considering the soils analyses in Table 4.3, an approximate initial level of fertilization should consist of adding 80 lbs/acre of phosphorous pentoxide (P_2O_5) and 64 lbs/acre of nitrogen (N) to the soil. Fertilizer suppliers can mix different chemical formulations to achieve the above approximate elemental combinations, such as ammonium phosphate-sulfate ($NH_4\ H_2PO_4 \cdot (NH_4)_2\ SO_4$), with an NPK rating of 16-20-0. This level of fertilization should be adequate for most of the sites. The nitrogen applied at this time is primarily to take care of the nitrogen requirements for decomposition of the mulch. A light application of nitrogen (20-30 lbs/acre) may be applied the second year to help sustain growth and productivity until vegetation is well established and some nitrogen fixing plants are established.

As phosphorus is fairly immobile in the soil, a second application will not be needed.

4.7.2 Equipment

For reseeding large areas, a tractor and seed drill should be used. For small areas, the seed can be hand broadcast and lightly raked. For applying fertilizer, a commercial fertilizer spreader pulled behind a farm tractor can be used for larger areas. For small sites a cyclone or hand held centrifugal spreader can be used to distribute fertilizer. This will help regulate the flow and insure even distribution.

4.8 SUMMARY OF RECOMMENDED PROCEDURES

In summary, M-K feels that for the majority of Atlas Minerals' sites, the minimum level of activity needed to provide a good likelihood of adequate revegetation in the most practical and cost effective manner can be obtained using the following procedures:

- Regrading and recontouring
- Ripping and/or discing
- Fertilizing
- Seeding
- Mulching and crimping

Regrading and recontouring are done to reduce erosion potential and maximize water availability. Ripping and discing are undertaken to develop a suitably loosened and firm seedbed. Fertilizer is recommended to provide nutrients for the decomposition of mulch. Without fertilizer addition the nominal amounts of nutrients present in the soil will be absorbed by microbes during decomposition of the organic matter. This would effectively decrease the soil nitrogen content.

Drill seeding is recommended for larger sites. Broadcast seeding at twice the rate of drill seeding can be used for small sites.

Mulching is a commonly used technique which enhances seedling establishment and helps conserve soil moisture. Mulching has been successfully used for many years on dry land reseeding projects. It is considered practical on the majority of sites since rainfall is sufficient to allow seed germination.

If topsoil is available for use in revegetation of some sites, mulch may not be necessary to adequately revegetate these sites. Before the mulch requirement can be dispensed with, small scale demonstration plots should be successfully revegetated to show the capability of topsoil alone to support permanent vegetation. After a successful demonstration, mulch should not be required if adequate topsoil is available.

Due to aridity, unavailability of suitable topsoil, and hot climate, potential for successful establishment of vegetation is considered limited at the following Utah mine sites:

- Cactus Rat
- Four Corners #2 and #6
- Happy Jack
- Probe
- Radium King
- Snow

Given the limited extent of natural vegetation in surrounding undisturbed areas, it is recommended that only minimal reclamation efforts be undertaken at these sites. Procedures recommended here are limited to:

- Regrading and recontouring
- Ripping and/or discing
- Seeding

Regrading is not recommended for the extensive angle of repose slopes at the Snow and Probe mines, because of the existence in the area of similar natural angle of repose slopes. Seeding is not recommended as being practical on these slopes and erosion impacts should be minimal. Regrading should be undertaken at these sites when they can be blended with surrounding natural topography and to decrease slopes to allow reseeding. Transplants should be considered for these sites.

Chances of successful revegetation are lower on these dry sites than at the majority of sites in the LaSal-Monticello vicinity and in Colorado. Because of the greater likelihood of poor revegetation, the additional expenditures required to mulch and fertilize these sites are considered impractical.

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4.9 RECLAMATION COST ESTIMATES

Costs presented here are on a unit cost per hour basis for certain operations, or on a cost per acre basis. Where costs per acre could be estimated, these estimates are presented. However, due to the variability and sizes of different sites, for certain operations such as regrading, costs per acre can not be estimated. One site may require several days of regrading while another site may require only a few hours of regrading. These cost estimates are based on M-K's experience, however, many factors such as local costs and available labor may vary these estimates substantially. Costs are strictly for labor and equipment operation, assuming subcontractor's rates. Overhead and benefit costs are not included for laborers. Cost estimates are presented for the following operations:

<u>Trash Removal</u>

- Dump Truck - 10-12 yd^3 @ $60.00/hr.
- Front-end loader - 3-5 yd^3 @ $60.00/hr.
- Two equipment operators - @ $15.50/hr. each

Topsoil Removal and Replacement

- D-6 dozer @ $60.00/hr.
- Operator - $15.50/hr.
- Alternative: Small self loading scraper - (10-20 yd^3 capacity) @ $125.00/hr.

If the scraper is used to pick up and stockpile topsoil additional time will be required for transporting the soil from salvage to stockpile and back.

Regrading and Recontouring

- D-6 dozer or equivalent - @ $60.00/hr.
- Operator - $15.50/hr.

Contour Furrowing

- D-6 dozer or equivalent with tilt or angle dozer blade - $60.00/hr.
- Alternative: Motor grader (50-80 hp) - $80.00/hr.
- Alternative: Farm tractor (60 hp) with disc furrower - $30.00/hr.
- Operator - $15.50/hr.

Final Seedbed Preparation

- D-6 dozer with multishank ripper or equivalent - $80.00/hr. + $15.50/hr. for operator.
- Discing - $110.00/Ac. - Large heavy duty disc with 24" blades.

Revegetation

• Drill seeding consisting of:		
Seed (average cost)		$145.00/Ac.
Application (Tractor, Seeder and Operator)	Total	$ 40.00/Ac.
		$185.00/Ac.
• Broadcasting consisting of:		
Seed (average cost)		$290.00/Ac.
Application		$ 40.00/Ac.
	Total	$330.00/Ac.
• Transplanting (300 plts/Ac.) consisting of:		
Seedlings (At $150.00 per 1,000)		$ 50.00[1]
Transplanting (hand planting)		$ 65.00/Ac.
	Total	$115.00/Ac.

Mulching and Crimping

Grass hay - 2 tons/acre

• Mulch - $175.00/ton x 2 -		$350.00/Ac.
• Application - Tractor, Trailer, and Mulcher -		$100.00/Ac.
• Crimping - Tractor and Crimper (cost includes operator)		$ 40.00/Ac.
	Total	$490.00/Ac.

Weed Control

• Mechanical -	$ 60.00/Ac.
• Chemical - (cost includes operator)	$100.00/Ac.

[1]This cost is extremely variable as price depends on quantity, size and availability of seedlings.

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Interseeding and Fertilizing

- Interseeding (cost includes operator) - \$135.00/Ac.
- Fertilizing - 5-80# bags (16-20-0) = 80# P_2O_5 and 64# N/Ac. Cost = \$10.00/bag x 5 = \$50.00 + \$40.00 Application = \$90.00/Ac. (cost includes operator).

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5.0 MONITORING METHODOLOGY AND COST ESTIMATES

5.1 GENERAL

Utah mining and reclamation regulations require that disturbed lands be revegetated to a cover level of at least 70 percent of the vegetative cover in comparable, adjacent undisturbed areas. Consistent monitoring for 3 to 5 years following reclamation activities will help to determine the success of the revegetation program. It is the responsibility of Atlas Minerals to demonstrate to the State that revegetation has been successfully accomplished in order to be released from their liabilities.

Reference areas or sites that are representative of the surrounding undisturbed vegetation will have to be selected for each of the revegetated sites. These reference areas will be used for comparison or as a standard for establishing vegetation.

If there are several sites that are located close together and if the vegetation is comparable between sites, one reference area that is representative of all the sites may be selected. There are no requirements regulating the size of the reference area as long as it is representative of the surrounding vegetation. Depending upon the variability of the vegetation, the size of the reference area should be between one and five acres. When vegetation is uniform, reference areas can be small. Reference areas should reflect the range of vegetation variation in the area. Reference areas should be chosen to be comparable to revegetated mine site areas, in terms of topography, slope, and exposure. This should tend to make comparisons between revegetated and reference areas more comparable.

5.2 MONITORING METHODS

Herbaceous Vegetation

Herbaceous vegetation on both the disturbed sites and the reference areas can be monitored utilizing line point transects. A minimum of three but not more than ten transects should be run on each site (on both revegetated and natural areas). The transects will be 25 meters long with readings taken every 50 centimeters. A steel tape should be used for the transect measurements. The reading should be taken at the 50cm interval marks where the tape intersects the ground surface. If vegetation is present, the plant species should be recorded. If no vegetation is present, plant litter, bare ground, or rock will be recorded. The number of plant hits as a percentage of total hits will be the percent ground cover of herbaceous vegetation.

Shrub and Tree Vegetation

Woody vegetation will be monitored using the line intercept method. This method measures the amount of vegetation that intercepts the transect line. It is utilized simply by measuring distances along the tape where shrub and tree species canopies intersect the tape line. Intercept distances are totaled for each species. To determine percent vegetation cover, the total number of centimeters of canopies that have intercepted the line are divided by the total number of centimeters (2,500) in the transect. Data for both herbaceous and woody vegetation can be obtained from the same transects.

Observational Monitoring

It is not necessary to collect quantitative data every year. The main purpose in collecting quantitative data will be to provide documentation to the State on the level of revegetation success. Frequent visual observations of the sites will provide a gross but satisfactory indication of the level of revegetation cover and growth success. Observational data such as signs of erosion, plant vigor, and wildlife utilization can be collected throughout the year. This data will also give an indication as to the success of the revegetation plantings.

Time of Monitoring

Observations to evaluate vegetative cover should be made at least once a year. If quantitative data are to be collected the vegetation should be at or near peak growth, sometime around mid-summer. It is important that the data be collected at the same phenological growth stage each year. Accurate comparisons can then be made to determine the percent vegetative cover and the difference in cover from year to year.

Data collected from the various transects within each site should be averaged together with this data. A T-test statistical comparison can be computed to compare the revegetated areas with the reference areas to determine if cover is comparable between the sites.

Monitoring Costs

In order to assess cost figures, we have assumed measuring an average of ten transects per site, five for the revegetated area and five for the reference area.

It will take approximately 1½ man-days per site for one person to conduct the transects and work up the data.

With a consultant man-day labor rate of $250 per day, the cost for monitoring one site annually will be between $300 to $375 dollars. Total labor cost for monitoring all the sites annually will be between $12,000 and $15,000. This total cost may vary depending upon the actual number of transects that must be taken and the labor rate for a subcontractor. Not all sites will require annual quantitative measurements.

Other direct expenses such as travel to the area, food, and lodging would be in addition to labor costs.

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